

Figure 1. Index map showing locations of measured sections.

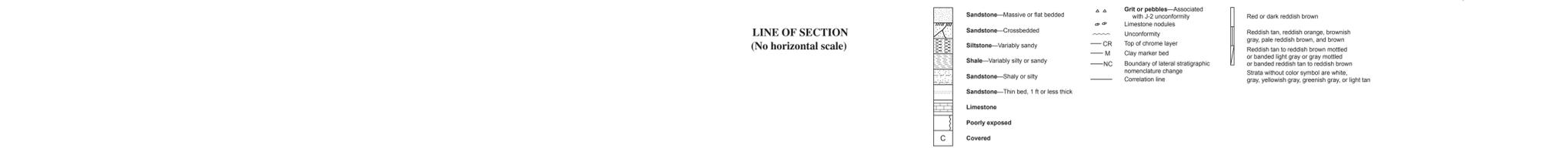
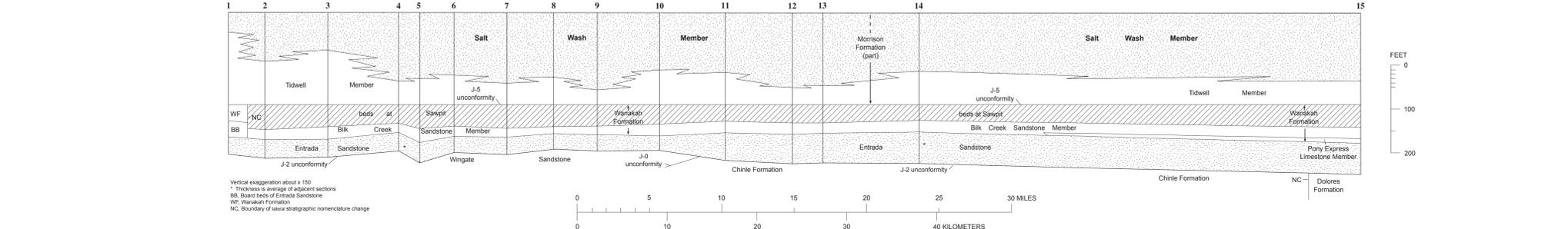


Figure 2. Map showing location of study area. RV, Rabbit Valley; SV, Salt Valley.



RESTORED STRATIGRAPHIC DIAGRAM

**NOTE**

The Middle Jurassic San Rafael Group in west-central Colorado (figs. 1, 2) consists mainly of sandstone, siltstone, and minor shale and limestone. The strata are exposed in deep canyons that dissect the northeast flank of the Uncompahgre Plateau from Bridgeport to Dry Creek Basin (fig. 1), but for a considerable distance southeast of Dry Creek Basin they are concealed beneath the surface near Ouray. The San Rafael Group is overlain by the Upper Jurassic Morrison Formation and is underlain by either the Lower Jurassic Wingate Sandstone or the Upper Triassic Chinle and equivalent Dolores Formations.

In the study area, three unconformities are associated with the rocks described herein. The boundaries of the San Rafael Group are formed by two of the unconformities—termed J-2 at the base and J-5 at the top. The third unconformity, the J-6 surface, separates the Wingate Sandstone from the Chinle Formation (Pipiringos and O'Sullivan, 1978). The J-5 unconformity is the datum used to construct the line of graphic sections and the restored stratigraphic diagram. The locations and names of 15 measured sections of this study are given in table 1 and shown in figure 1.

**UPPER TRIASSIC ROCKS**

The Chinle Formation underlies the Entrada Sandstone southward from Roubidoux Creek around Ouray; the equivalent Dolores Formation is exposed beneath the Entrada between sections 14 and 15. The Dolores and Chinle Formations are red bed sequences consisting of limestone conglomerate, fine-grained sandstones, siltstone, and impure limestone (Barbark, 1930, p. 169; Lohman, 1965, p. 22). In the Grand Junction area, the Chinle is about 100 ft thick (Lohman, 1965, p. 22). At Traver Creek, a tributary to Roubidoux Creek, the Chinle Formation is 290 ft thick and thins southward to 440 ft at Red Canyon (Craig and others, 1959, section nos. 212 and 165, respectively). The Dolores Formation is 575 ft thick (Bush and others, 1959, p. 320) along the San Miguel River near Placerville, and 90–125 ft thick along the Uncompahgre River between Ouray and Ridgway (O'Sullivan, 1992a).

**WINGATE SANDSTONE**

The Lower Jurassic Wingate Sandstone is mainly a crossbedded, very fine grained sandstone of eolian origin and underlies the San Rafael Group from Bridgeport to Monitor Creek (secs. 1–10). The Wingate Sandstone is as much as 270 ft thick in the Colorado National Monument area (Lohman, 1965, p. 26). Near Escalante Forks, it is almost 200 ft thick (Craig and others, 1959, section no. 149) and is completely beveled out under the J-2 unconformity between Monitor and Roubidoux Creeks between secs. 10 and 11. The Wingate Sandstone is the oldest of the three formations that make up the Lower Jurassic Glen Canyon Group and is overlain elsewhere (west of the study area) in ascending order, by the Kayenta Formation and Navajo Sandstone. The Kayenta and Navajo are also truncated by the J-2 unconformity west of Bridgeport (O'Sullivan and Pipiringos, 1983).

**SAN RAFAEL GROUP**

The Middle Jurassic San Rafael Group consists of the Entrada Sandstone overlain by the Wapak Formation (fig. 3). The thickness of the San Rafael Group averages about 120 ft, ranging from 103 ft at Escalante Forks A (sec. 8) to 160 ft at North Ouray (sec. 15).

**ENTRADA SANDSTONE**

The Entrada Sandstone is not subdivided in most of the area although it is an equivalent of the Slick Rock Member mapped in nearby Colorado National Monument (Scott and others, 2001). At Bridgeport (sec. 1) the informally named "board beds" are at the top of the Entrada and overlie the Slick Rock Member equivalent (fig. 3). The Entrada Sandstone, in most of the area, is gray, reddish tan, and reddish brown, and consists mainly of fine-grained to very fine grained sandstone, with disseminated, sparse, well-rounded, medium grains of clear quartz. The formation is arranged in an alternating sequence of crossbedded and flatbedded units or beds. The crossbedded units are considered eolian dune deposits; the flatbedded units are interpreted as interdune deposits.

A notable feature of the Entrada Sandstone is the chrome layer found at Dry Creek Basin (sec. 14). The thin chrome layer makes a striking light-green band about 20 ft below the top of the Entrada Sandstone. An atomic absorption analysis of a grab sample from the chrome layer by R. Mahrt (U.S. Geological Survey, undated written comment) showed about 60 ppm chromium, 12 ppm copper, and an average of about 40 ppm vanadium. The chrome layer is undoubtedly the same as the chrome layer in the Placerville area of the San Miguel River that was described by Bush and

others (1959, p. 373–376) and by Fischer (1968).

The board beds constitute the upper part of the Entrada Sandstone at Bridgeport (sec. 1), where they are 20 ft thick and reddish-brown mottled gray in color. The board beds weather unevenly into a series of steps or benches and resemble at places a horizontal stack of wooden boards each of different thickness. The unit contrasts markedly with the smooth rounded cliffs of the underlying parts of the Entrada Sandstone. The bedding, even and mostly flat, indicates that most if not all of the board beds were probably deposited in a body of quiet water. Scott and others (2001, p. 16) believed the unit was laid down "in a wet sandflat environment in a coastal setting." South of Bridgeport, the board beds grade into the lower part of the Wapak Formation, but they can be recognized as far west as Rabbit Valley, 40 mi from Bridgeport (fig. 2), where the unit grades into a smooth rounded cliff indistinguishable from the underlying parts of the Entrada Sandstone (O'Sullivan and Pipiringos, 1983).

**WANAKAH FORMATION**

The Wapak Formation, of marginal marine origin, conformably overlies the Entrada Sandstone. The formation, recognized along the entire length of the line of section, was mapped in the Colorado National Monument (Scott and others, 2001). It was named by Barbark (1930, p. 172) for exposures at the Wapak mine north of Ouray. At Bridgeport (sec. 1) the Wapak is not differentiated but elsewhere four subdivisions are recognized. The Pony Express Limestone Member overlies the Entrada Sandstone around North Ouray (sec. 15) and was named by Barbark (1930, p. 172) for the Pony Express mine, which lies about 4 mi north of Ouray. The Blk Creek Sandstone Member (Goldman and Spencer, 1941, p. 1750) was named for Blk Creek, which drains into the San Miguel River about 4 mi west of Telluride (fig. 1). This unit, capped by the distinctive "carnelian sandstone marker bed" as well as the informally named "beds at Sawpit" at the top of the Wapak Formation, can be recognized in all sections from Little Dominguez (sec. 2) to North Ouray (sec. 15). The Wapak Formation averages about 70 ft in thickness, ranging from 34 ft at Bridgeport (sec. 1) to 8 ft at Escalante Creek 2 (sec. 5).

The Pony Express Limestone Member has a distinctive lithologic unit within the San Rafael Group. The member is at the base of the Wapak Formation only at North Ouray (sec. 15) where it is about 8 ft thick. The environment of deposition of the Pony Express is uncertain, both marine and lacustrine origins have been proposed (Adler, 1974; Kirkland and others, 1995; Ridgley and Galhabber, 1983; and Tanner, 1970). The Pony Express is mainly dark-gray limestone, with fresh surfaces having a petroleum odor. Some exposures, near Ouray, show gray shale and sandstone interbedded with the limestone, and gypsum is also locally present. From North Ouray (sec. 15) the Pony Express Limestone Member dips northward beneath younger rocks: at Dry Creek Basin (sec. 14), where the Wapak reappears in outcrop, the Pony Express is absent. The Pony Express probably extends in the subsurface some distance northward from North Ouray (sec. 15) because it is exposed around Placerville (Bush and others, 1959, p. 325) to the west of Ouray and it crops out locally in the Black Canyon east of Olathe (O'Sullivan, 1992a).

The Blk Creek Sandstone Member overlies the Entrada Sandstone throughout most of the area; near Ouray it overlies the Pony Express Limestone Member. The Blk Creek is recognized as far north as Little Dominguez (sec. 2). At Bridgeport, 2.5 mi to the north (sec. 1), equivalents of the Blk Creek are in the lower part of the board beds of the Entrada Sandstone. The Blk Creek is gray near Ouray and red and brown elsewhere. Bedding in the study area is flat or not apparent. The member averages about 24 ft in thickness, ranging from 16 ft at Escalante Forks A (sec. 8) to 33 ft at Escalante Creek 2 (sec. 5).

The Blk Creek Sandstone Member is capped by the distinctive "carnelian sandstone marker bed." The name is derived from the presence at many places of "autochthonous red chert" scattered through it to some extent but more characteristically on its upper surface" (Goldman and Spencer, 1941, p. 1749). The sandstone is poorly sorted and mostly fine grained, but contains sparse to abundant, rounded, coarse quartz grains as much as about 1 mm across. Bedding is flat or not apparent. The carnelian sandstone varies in thickness from 1.2 ft at both Roubidoux C (sec. 13) and North Ouray (sec. 15) to 6.3 ft at Escalante Creek 2 (sec. 5). The unit is present at Little Dominguez (sec. 2) but was not recognized at Bridgeport (sec. 1). It also pinches out near Pilon on the southwest side of the Uncompahgre Plateau (O'Sullivan, 1992). Bush and others (1960, p. 441) noted that the carnelian marker bed "is remarkably persistent over an area covering perhaps several thousand square miles."

The Wapak Formation at Bridgeport (sec. 1), although not shown to be subdivided, is made up of a lower red unit about 7 ft thick overlain by a green unit about 28 ft thick. The two units can be

traced because of their striking color contrast as far west as Rabbit Valley where the red unit thickens and replaces the green unit (O'Sullivan and Pipiringos, 1983). The red unit consists mainly of red and minor greenish-gray siltstone, thin white and red sandstone beds generally less than 1 ft thick, and thinner beds of red, purple, and black clay shale. In the Grand Junction area, the red unit is a useful guide for water-well drilling "by alerting them that the main artesian aquifer—the Entrada Sandstone, is not far below" (Luzark, 1965, p. 47). The green unit consists of greenish-gray and brownish-gray siltstone and shale, brownish-gray, thin limestone beds and nodules, and minor layers of gray sandstone. South of Bridgeport, equivalents of the red and green units are in the beds at Sawpit.

The beds at Sawpit are recognized above the Blk Creek Sandstone Member from Little Dominguez (sec. 2) to North Ouray (sec. 15). The unit is mostly a sequence of red sandstone and siltstone beds generally less than 5 ft thick. The beds at Sawpit average about 47 ft in thickness, ranging from 35 ft at Dry Creek Basin (sec. 14) to 60 ft at Little Dominguez (sec. 2). A notable feature in the beds at Sawpit and in the Wapak at Bridgeport (sec. 1) is the marker clay ("M" on the line of section) and an associated underlying thin gray fossiliferous sandstone bed. The fossil bed is fine to medium grained, flatbedded, and in places ripple marked. The bed averages about 0.8 ft in thickness and ranges from 0.1 ft at Bridgeport (sec. 1) to 1.5 ft at Escalante Forks A (sec. 8), Roubidoux B (sec. 12), and Roubidoux C (sec. 13). The fossil bed rests directly on the Entrada Sandstone at Bridgeport (sec. 1) and it and the overlying marker clay are not recognized at North Ouray (sec. 15). Elsewhere, the fossil bed lies approximately 37 ft above the Entrada Sandstone, ranging from about 30 ft at Escalante Forks (sec. 7) to about 50 ft at Escalante Creek 2 (sec. 5).

The fossil bed contains a sparse record of organic remains. At Little Dominguez (sec. 2) a single poorly preserved pelecypod has been identified as possibly *Modiolus cf. M. submarginatus* (Modiol by S.G. Good (University of Colorado, written commun., March 11, 1997). *Modiolus* indicates shallow marine waters (Imray, 1964, p. C7). The waters may have been brackish rather than of normal marine salinity (P. Peterson, U.S. Geological Survey, written commun., February 24, 2004). The fossil bed locally contains molds probably of brachiopods that are similar to *Mortilia* (S.G. Good, written commun., February 1, 1988). Possible sponge spicules and fossils of uncertain classification have been noted here and there in the fossil bed. Near the mouth of Escalante Creek, pelecypod fossils discovered by Holmes (1960, p. 107) and examined by J.B. Reesick, Jr. (U.S. Geological Survey) belong to an unnamed species of *Mytilus* of marine origin. Small calcareous tubes, possibly formed by serpulid worms, are also present at the same locality (Holmes, 1960, p. 107). A comparison of the section measured by Holmes (1960, fig. 30) with Escalante Creek 1 (sec. 4) indicates that the fossil horizon described by Holmes is the same as the fossil bed of this report.

The marker clay ("M" on the line of section) is gray or greenish gray at Monitor Creek (sec. 10), Roubidoux A (sec. 11), and Dry Creek Basin (sec. 14). Elsewhere, it is reddish brown to purple. The clay averages about 0.4 ft in thickness, ranging from 0.1 ft at Escalante Forks A (sec. 8) to 0.8 ft at the bed at Little Dominguez (sec. 2) and Escalante Forks 1 (sec. 7).

**MORRION FORMATION**

The Upper Jurassic Morrison Formation consists of three members—in ascending order, the Tidwell Member, the Salt Wash Member, and the Bushy Basin Member. In the study area, the Salt Wash Member is 200–400 ft thick and the Bushy Basin Member is 200–350 ft thick (Craig and others, 1959, figs. 21, 29). At Bridgeport, 2.5 mi to the north (sec. 1), equivalents of the Salt Wash and Bushy Basin members are interbedded with red and gray siltstone and shale. The overlying slope-forming Beatty Basin is mostly gray, green, and red and contains minor amounts of limestone and conglomeratic sandstone. Only the lower part of the Morrison Formation is plotted on the line of section and restored stratigraphic diagram.

The Tidwell Member mostly forms a steep slope between the thick prominent sandstone ledges of the Salt Wash Member and the underlying Wapak Formation. Bed A marks the base of the Tidwell, which also includes two separately recognized lentular sandstone beds possibly of eolian origin. The Tidwell averages about 75 ft in thickness, ranging from 34 ft at Dry Fork (sec. 9) to 166 ft at Bridgeport (sec. 1).

The complete coarse yellow marker bed, bed A, is gray to yellowish-gray, fine-grained sandstone that contains coarse to very coarse grains of quartz and chert. Bedding in flat and commonly has well-formed current ripple marks. Some minor low-angle crossbeds were observed at Bridgeport (sec. 1) and Roubidoux B (sec. 12). This gray siltstone lenses are interbedded at many localities. Bed A averages 11 ft in thickness, ranging from 5.3 ft at Escalante Forks (sec. 7) to 21.3 ft at North Ouray (sec. 15).

The base of the Morrison Formation is placed at the J-5 unconformity, which underlies bed A. The J-5 unconformity is a useful, convenient, and widespread stratigraphic break in Jurassic rocks. In the San Rafael Swell of Utah, Gilby (1929, p. 111) placed the base of the Morrison Formation at the J-5 unconformity that is "both angular and erosional" when he extended the formation name into Utah. Moreover, the unconformity selected by Gilby (1929, p. 110) is the upper boundary of the San Rafael Group. This unconformity is now recognized as the J-5 unconformity. The J-5 unconformity and bed A, however, have been misidentified at numerous localities in Colorado and Utah. At Bridgeport, for example, the J-5 unconformity and bed A were previously placed directly above the board beds of the Entrada Sandstone by O'Sullivan and Pipiringos (1983). A higher unit, previously designated sandstone bed B at Bridgeport (fig. 3), is now recognized as bed A. Also, some units previously assigned to the basal part of the Morrison Formation are now included with the Wapak Formation.

Similarly, bed A and the associated J-5 unconformity were incorrectly identified west of the study area—for example, in reports extending from Bridgeport west to Dewey Bridge (O'Sullivan and Pipiringos, 1983), from Dewey Bridge to Salt Valley (O'Sullivan, 1981), and from Dewey Bridge to Uravan (O'Sullivan, 1984). The units identified as bed B' and bed A' in those reports were correctly identified as "bed A" and a sandstone bed within the Wapak Formation, respectively, based on later work from Uravan to Telluride (O'Sullivan, 1980). The J-5 unconformity previously identified at Bridgeport (fig. 3) and in other parts of western Colorado and eastern Utah may instead be an extensive major-creeping surface similar to those within the San Rafael Group of southeastern Utah as described by Carr-Crouching and Kocum (1998).

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Table 1. Number, name, and location of measured sections

Section No.	Name	Location
1	Bridgeport	SW1/4 SE1/4 NE1/4 sec. 7, and NW1/4 NE1/4 NE1/4 sec. 18, T. 14 S., R. 88 W.
2	Little Dominguez	SW1/4 SW1/4 NE1/4 sec. 29 and NE1/4 NE1/4 NE1/4 sec. 30, T. 14 S., R. 98 W.
3	Dominguez	N1/2 lot 8, sec. 20, T. 4 S., R. 3 E.
4	Escalante Fork A	NE1/4 NE1/4 NW1/4 sec. 31, T. 15 S., R. 97 W.
5	Escalante Creek 2	SE1/4 SW1/4 sec. 26, T. 15 S., R. 98 W., and W1/2 lot 4 and NW1/4 NW1/4 SW1/4 sec. 11, T. 51 N., R. 13 W.
6	Escalante Creek 3	NE1/4 SW1/4 NW1/4 and SE1/4 SW1/4 NW1/4, sec. 21, T. 51 N., R. 13 W.
7	Escalante Forks	SE1/4 NW1/4 NW1/4 and NE1/4 SW1/4 NW1/4, sec. 36, T. 51 N., R. 14 W.
8	Escalante Forks A	NE1/4 NE1/4 NE1/4 sec. 14, T. 50 N., R. 14 W.
9	Dry Fork	NW1/4 SE1/4 NE1/4, sec. 20, T. 50 N., R. 13 W.
10	Monitor Creek	SW1/4 NW1/4 NW1/4, sec. 30, T. 50 N., R. 12 W.
11	Roubidoux A	NE1/4 SE1/4 SW1/4 and NE1/4 NW1/4 SE1/4, sec. 26, T. 50 N., R. 12 W.
12	Roubidoux B	NE1/4 SE1/4 SW1/4 and SE1/4 SE1/4 NW1/4, sec. 16, and NE1/4 NE1/4 NW1/4 and NW1/4 NW1/4 NW1/4, sec. 21, T. 49 N., R. 12 W.
13	Roubidoux C	SE1/4 SE1/4 SW1/4, sec. 27, T. 49 N., R. 12 W.
14	Dry Creek Basin	NE1/4 SW1/4 SE1/4 and NW1/4 SW1/4 SE1/4 and SE1/4 lot 15 and NW1/4 lot 16, sec. 4, T. 49 N., R. 11 W.
15	North Ouray	NW1/4 NE1/4 NW1/4, sec. 38, T. 45 N., R. 8 W.

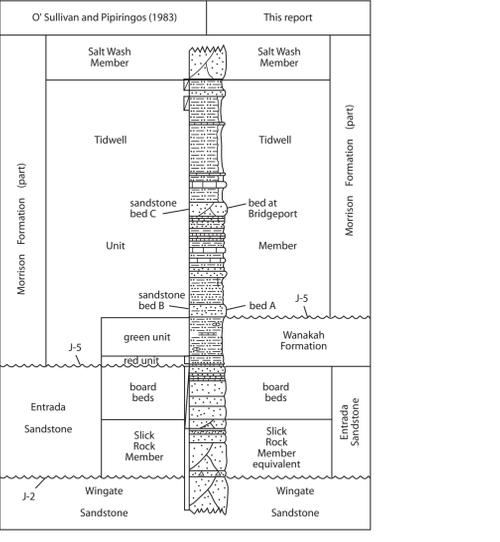


Figure 3. Different nomenclature used at Bridgeport (sec. 1).

**CORRELATION OF MIDDLE JURASSIC SAN RAFAEL GROUP AND RELATED ROCKS FROM BRIDGEPORT TO OURAY IN WESTERN COLORADO**

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